Deep Learning in Mechanical Metamaterials: From Prediction and Generation to Inverse Design

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Abstract

Mechanical metamaterials are meticulously designed structures with exceptional mechanical properties determined by their microstructures and constituent materials. Tailoring their material and geometric distribution unlocks the potential to achieve unprecedented bulk properties and functions. However, current mechanical metamaterial design considerably relies on experienced designers' inspiration through trial and error, while investigating their mechanical properties and responses entails time■consuming mechanical testing or computationally expensive simulations. Nevertheless, recent advancements in deep learning have revolutionized the design process of mechanical metamaterials, enabling property prediction and geometry generation without prior knowledge. Furthermore, deep generative models can transform conventional forward design into inverse design. Many recent studies on the implementation of deep learning in mechanical metamaterials are highly specialized, and their pros and cons may not be immediately evident. This critical review provides a comprehensive overview of the capabilities of deep learning in property prediction, geometry generation, and inverse design of mechanical metamaterials. Additionally, this review highlights the potential of leveraging deep learning to create universally applicable datasets, intelligently designed metamaterials, and material intelligence. This article is expected to be valuable not only to researchers working on mechanical metamaterials but also those in the field of materials informatics.